JOURNAL OF CHEMICAL PROCESS ENGINEERING
p-ISSN : 2527-4457
e-ISSN : 2655-2957
Vol. 10 No. 2 (2025)

Research Article

Effectiveness of Psidium guajava Leaf Extract as a Corrosion Inhibitor for Low Carbon Steel in Seawater

Rahmayanti, Irsyad, Muh. Azis Albar J*, Saifullah S Thahah

Mineral Chemical Engineering Study Program, Politeknik Industri Logam Morowali, Trans Sulawesi Road, Desa Labota, Kecamatan Bahodopi, Morowali Indonesia.

Artikel Histori: Submitted 1 Oct 2025, **Revised:** 21 Nov 2025, **Accepted:** 22 Nov 2025, **Online:** 30 Nov 2025.

https://doi.org/10.33096/jcpe.v10i2.2166

ABSTRACT: *Corrosion remains a critical challenge across various industrial sectors due to its substantial economic, environmental, and safety implications. Low carbon steel, despite its favorable mechanical properties and cost-effectiveness, is highly susceptible to corrosion, particularly in chloride-rich environments such as seawater. In recent years, the use of natural-based corrosion inhibitors has gained increasing attention as an environmentally friendly alternative to synthetic chemicals. This study investigates the effectiveness of guava (Psidium guajava) leaf extract, which contains active compounds such as tannins and polyphenols, as a corrosion inhibitor for low carbon steel in a seawater medium. The weight loss method was employed to determine corrosion rates, with inhibitor concentrations ranging from 7% to 11% over an immersion period of 288 hours. The results demonstrate that a concentration of 10% produced the most significant inhibitory effect, reducing the corrosion rate to 0.00011 mils per year and achieving a maximum inhibition efficiency of 73.17%. Other concentrations yielded efficiencies between 56.09% and 60.97%. These findings indicate that guava leaf extract has considerable potential as an effective and sustainable bioinhibitor capable of reducing corrosion in low carbon steel under harsh marine conditions. Overall, this study contributes to the development of green corrosion mitigation strategies and highlights the viability of natural plant extracts as promising alternatives to conventional synthetic inhibitors.*

Keywords: *Corrosion, Bioinhibitor, Guava Leaf Extract, Low Carbon Steel, Seawater.*

1. INTRODUCTION

Low carbon steel, defined by carbon content between 0.05–0.30 wt %, is widely employed in construction, automotive, and heavy-equipment manufacturing due to its favorable mechanical properties and relatively low production costs [1]. However, one of its weaknesses is its low corrosion resistance, especially in highly aggressive environments such as seawater. In marine conditions, chloride ions (Cl^-), oxygen levels, high humidity, and flow activity accelerate metal degradation, resulting in significant corrosion rates [2].

Corrosion is an electrochemical phenomenon in which metals undergo oxidation (anodic reaction: release of electrons) and reduction (cathodic reaction) on surfaces in contact with corrosive agents [3]. As a result, metal structures experience a decrease in strength, mechanical integrity, and sometimes structural failure if left unaddressed [4]. Corrosion in marine environments also has a major economic impact, such as increased maintenance costs and downtime, damage to marine infrastructure, and environmental damage due to dissolved metals or corrosion products carried into ecosystems [5]. Recent studies indicate that economic losses due to marine corrosion amount to several percent of the national GDP in coastal countries, emphasizing the urgency of effective corrosion control [6].

To reduce corrosion, various methods have been proposed and practiced, namely coatings, employing stainless steel or other corrosion-resistant alloys, applying cathodic protection methods, and utilizing chemical inhibitors are among the strategies commonly adopted to mitigate corrosion [7]. Among these methods, inhibitors have the advantage of flexibility of application and lower potential costs, especially when using natural materials (green inhibitors/bioinhibitors) [8]. Natural materials offer the additional advantages of

Published by
Department of Chemical Engineering
Faculty of Industrial Technology
Universitas Muslim Indonesia, Makassar
Address
Jalan Urip Sumohardjo km. 05 (Kampus 2 UMI) Makassar- Sulawesi Selatan
e-mail : jcpe@umi.ac.id

Corresponding Author *
azis@pilm.ac.id

environmental sustainability and better toxicological safety compared to synthetic compounds [9]. One of the natural material that has been extensively studied is guava leaf extract (Psidium guajava L.). Guava leaves contain active compounds such as flavonoids, tannins, terpenoids and, polyphenols, which can form complexes on metal surfaces or are adsorbed, thereby inhibiting anodic and cathodic reactions [10]. Recent studies report the high efficiency of guava extract in various corrosive media. Akbar et al. (2019) [8] reported that guava leaf extract at a maximum concentration of 25% provided up to ~97% efficiency in seawater media in a weight loss test. Meanwhile, Abdulwahab et al. (2022) [11] tested guava leaf extract on Al-Si-Mg alloys in a 3.5% Sodium Chloride (NaCl) solution and found that the efficiency could reach ~63% at a concentration of 0.5% (v/v) for the gravimetric method, and higher when using potentiodynamic polarization. However, specific studies on the effectiveness of guava leaf extract on low-carbon steel in seawater media, particularly regarding concentration variations, immersion time, and surface characterization, remain relatively limited. A related example is the research by Pusparizkita et al. (2023) [12] which discusses the corrosion behavior of carbon steel in artificial seawater without inhibitors, providing important baseline data for corrosion inhibition studies.

Based on these considerations, this study aims to evaluate the efficacy of guava leaf extract as a natural corrosion inhibitor on low-carbon steel in seawater. It is hoped that the results of this study will contribute to more sustainable, environmentally friendly, and economical corrosion control technology, as well as provide an alternative to the use of expensive synthetic inhibitors or those with problematic environmental impacts.

2. RESEARCH METHOD

This research was conducted using a laboratory experiment method with a quantitative approach. The main method used was the weight loss method, which involved comparing the initial mass and final mass of steel specimens after immersion in a test solution for a certain period.

The instruments employed in this research consisted of a hot plate, analytical balance, magnetic stirrer, blender, funnel, Erlenmeyer flask, measuring cup, diluting flask, caliper, measuring pipette, porcelain dish, furnace, desiccator, and sandpaper.

Meanwhile, the materials used consisted of fresh guava leaves, 70% ethanol as an extraction solvent, distilled water, ST37 low carbon steel, and seawater as a corrosive medium.

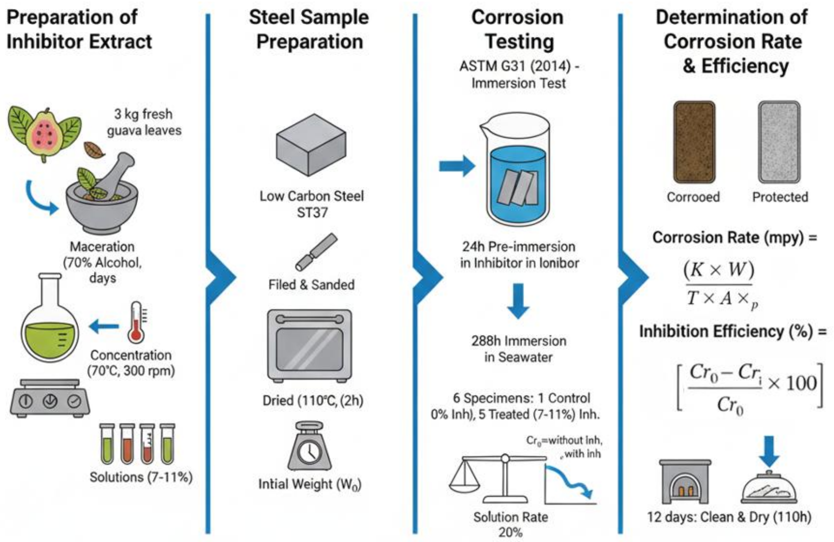

Figure 1. Graphical Abstract: Effectiveness of Psidium guajava Leaf Extract as a Corrosion Inhibitor for Low Carbon Steel in Seawater

2.1. Preparation of Inhibitor Extract

A total of 3 kg of fresh guava leaves were first washed thoroughly, then dried for 14 days. Once dry, the leaves underwent grinding with a blender until they became a fine powder. A total of 228.1 g of dry powder was extracted using the maceration method with 1 liter of 70% alcohol for two days. The maceration solution was then filtered using filter paper. A preliminary test was then conducted on the extraction filtrate to detect the content of tannins and other compounds that act as inhibitor agents. The test was carried out by adding 1 drop of 10% $FeCl_3$ solution to 10 ml of the extract filtrate, then observing the color change of the solution. If the solution turned greenish-black, this indicated the presence of tannins [13]. The remaining extract solution was then heated on a hot plate at 70°C and stirred at 300 rpm until a thick extract was formed [13]. This concentrated extract was diluted to make inhibitor solutions with concentrations of 7%, 8%, 9%, 10%, and 11%.

2.2. Steel Sample Preparation

Low carbon steel ST37 was cut into dimensions of ± 3.7 cm × 3.6 cm × 0.8 cm. The surface of the specimen was filed and sanded until shiny. The specimen was first rinsed with distilled water and subsequently dried in a furnace at 110 °C for 2 hours, then cooled in a desiccator and weighed for its initial weight.

2.3. Corrosion Testing

The specimens were divided into six parts, consisting of one control specimen without the use of an inhibitor and five treated specimens with various concentrations of inhibitor. Each specimen was first immersed in an inhibitor solution for 24 hours for the inhibition process, then continued with immersion in seawater for 288 hours. This procedure refers to the ASTM G31 (2014) [14] standard used to evaluate the level of corrosion and the effectiveness of inhibitor materials.

2.4. Determination of Corrosion Rate and Inhibition Efficiency

In the present study, the corrosion rate was assessed through the weight loss approach. This method is based on measuring the mass loss of specimens after the immersion process [15]. Calculation of the corrosion rate was performed using the following formula:

$$CR = \frac{K.W}{A.T.\rho} \quad \text{.......... (1)}$$

where:

CR = Corrosion rate (mpy)
K = Corrosion rate constant (534)
W = Mass difference (g)
T = Immersion time (hours)
A = Surface area (cm^2)
ρ = Density of carbon steel (g/cm^3)

When using inhibitors, it is important to know their efficiency. The performance of a corrosion inhibitor reflects its capability to reduce the degradation rate of metal surfaces. Its efficiency can be quantified using the following equation [16]:

$$\eta = \frac{Cro - Cri}{Cro} \times 100\% \quad \text{.......... (2)}$$

where:

η = Inhibitor efficiency (%)
Cro = Corrosion rate without inhibitor (mpy)
Cri = Corrosion rate with inhibitor (mpy)

On the 12th day, all specimens were removed from the corrosive medium and then cleaned of rust and dirt adhering to their surfaces by rinsing with distilled water. After that, the samples were dried using tissue paper until completely dry. To ensure complete dryness, the specimens were then heated in a furnace at 110°C for 2 hours. After the heating process, the specimens were cooled in a desiccator before being weighed to obtain their final weight. The determination of corrosion rate and inhibition efficiency was carried out through equations (1) and (2).

3. RESULTS AND DISCUSSION

The determination of corrosion rate and inhibitor efficiency in this study used the weight loss method. The calculation results are shown in Table 1.

Table 1. Data obtained from calculations of corrosion rate and inhibition efficiency

Concentration (%)	Weight Loss (gr)	Corrotion Rate (mpy)	Inhibition Efficiency (%)
0	0.0542	0.00041	0
7	0.0228	0.00018	56.10
8	0.0220	0.00017	58.54
9	0.0214	0.00016	60.98
10	0.0152	0.00011	73.17
11	0.0230	0.00018	56.10

Based on observations of Table 1, data on specimen mass loss after immersion for 288 hours and corrosion rates show that steel samples without inhibitor additives experienced the greatest mass loss. This phenomenon is caused by electrochemical interactions between iron (Fe) ions and components in seawater, including chloride ions, oxygen, and other dissolved substances [16]. The oxidation reaction on the anode surface is indicated by the reaction:

$$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$$

and accompanied by an oxygen reduction reaction at the cathode:

$${}^{1}/_{2}\,O_{2\,(g)} + H_2O_{(l)} + 2e^- \rightarrow 2OH^-_{(aq)}$$

3.1. The effect of guava leaf extract inhibitor concentration on corrosion rate

The relationship between inhibitor concentration and corrosion rate is presented more clearly in Figure:

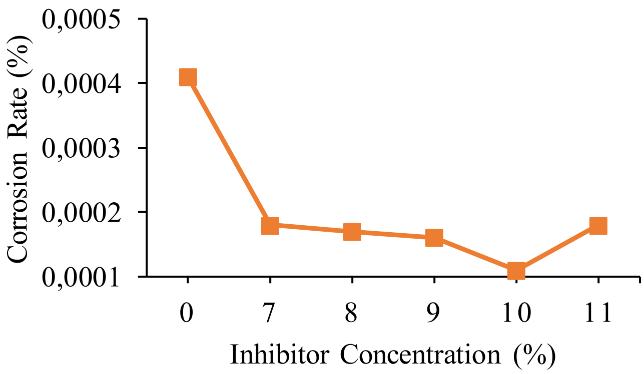

Figure 2. Graph showing the effect of guava leaf extract inhibitor concentration on corrosion rate

Figure 1 demonstrates how the concentration of guava leaf (Psidium guajava L.) extract influences the corrosion rate of low-carbon steel in a marine environment. Overall, the data indicate that increasing inhibitor concentration leads to a notable decrease in the corrosion rate up to an optimum level, after which a slight rise in corrosion rate is observed at higher concentrations. Under conditions without inhibitors (0%), the corrosion rate was recorded at 0.00041%, which was the highest value in this study. This shows that low carbon steel is very susceptible to attack by chloride ions (Cl^-) and dissolved oxygen in aggressive seawater media. According to Hermanto D et al. (2019), unprotected carbon steel experiences a high corrosion rate in salt solutions because chloride ions accelerate anodic ($Fe \rightarrow Fe^{2+} + 2e^-$) and cathodic ($O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$) reactions on metal surfaces [8]. This finding is consistent with the results reported by Gapsari F. et al. (2021), who demonstrated that chloride ions are a key factor in promoting the onset of pitting corrosion in carbon steel exposed to marine environments [17]. Furthermore, increasing the inhibitor concentration from 7% to 10%, a substantial decrease in corrosion rate occurred, from 0.00018% to 0.00011%. This indicates the active role of secondary metabolites in guava leaves, such as tannins, flavonoids, polyphenols, and terpenoids, the active compounds are able to adsorb onto the carbon steel surface, creating a protective film. This adsorptive layer suppresses oxidation at the anode as well as reduction at the cathode, demonstrating that the inhibitor exhibits mixed-type inhibitory behavior. A similar study was reported by Fazal et al. (2022), who found that increasing the concentration of guava extract can significantly reduce the rate of iron corrosion [17]. Similarly, research by Selvam et al. (2015) showed that guava leaf extract is effective in inhibiting steel corrosion in acidic solutions with an efficiency of more than 90% at the optimum concentration [18].

The optimum concentration was obtained at 10%, with the lowest corrosion rate value of 0.00011%. At this point, the carbon steel surface was almost completely covered by inhibitor molecules, resulting in a more homogeneous and stable protective layer. A recent study by Ezeamaku U et al. (2023) also reported that the optimal concentration of guava leaf extract provided the highest inhibition efficiency on aluminum, indicating a similar protective mechanism through the formation of an organic film on the metal surface [19].

However, at a concentration of 11%, there was a slight increase in mass loss, indicating a decrease in inhibitor effectiveness. The reduction in the inhibitory performance of guava leaf extract at 11% concentration can be attributed to multiple factors, although at that concentration the corrosion rate still decreased. One reason is the formation of a protective layer that is too thick or unstable on the metal surface, thereby inhibiting the adsorption process of active compounds such as tannins [20]. In addition, too high a concentration of inhibitor can cause the accumulation of compounds that are not well adsorbed, which ultimately reduces the overall inhibition efficiency [21].

3.2. The effect of guava leaf extract inhibitor concentration on inhibitor efficiency

The graph showing the relationship between the concentration of guava leaf extract inhibitors and the corrosion inhibition efficiency of ST37 low carbon steel is presented in the following figure.

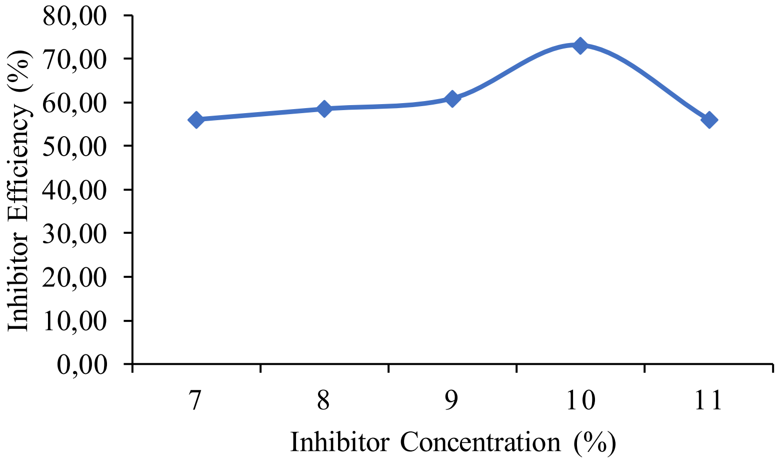

Figure 3. Graph showing the effect of guava leaf extract inhibitor concentration on inhibitor efficiency

From the graph in Figure 2, it can be seen that, in general, an increase in inhibitor concentration affects efficiency in a fluctuating manner: it increases at low concentrations until it reaches an optimum at 10%, then decreases at higher concentrations.

At a concentration of 7%, the inhibitor efficiency was 56.10% and increased slightly to 60.98% at a concentration of 9%. This increase indicates that bioactive compounds in guava leaf extract, such as flavonoids, tannins, and polyphenols, begin to adsorb onto the metal surface and form a protective layer that suppresses the corrosion rate. This is in line with Shwetha et al. (2024), who stated that an increase in bioinhibitor concentration generally expands the protected metal surface area, thereby increasing inhibition efficiency [22]. The inhibitor efficiency peaked at a concentration of 10%, which was 73.17%. This value is the optimum condition where the inhibitor molecules are maximally adsorbed and form a homogeneous protective layer on the surface of low carbon steel. This layer acts as a barrier to the diffusion of aggressive ions such as Cl^- from seawater, which accelerates corrosion. This phenomenon is consistent with the research by Selvam et al. (2015), who found that guava extract can act as an effective natural corrosion inhibitor with an efficiency of more than 90% in acidic media, reinforcing the finding that this bioinhibitor is effective in various [18].

However, at a concentration of 11%, the inhibitor efficiency dropped back to 56.10%. This decrease may be due to an excess of inhibitor molecules that cannot be adsorbed properly, causing the formation of a non-homogeneous layer, and interactions between a high number of inhibitor molecules can disrupt the regularity of the protective layer. This is in line with what Alao et al. (2022) reported, namely that at concentrations above the optimum, inhibitor efficiency can decrease because the inhibitor layer becomes unstable or forms ineffective aggregates [23]. The study by Rizi et al. (2023) states that natural inhibitors generally work through a combination of physical and chemical adsorption, with the highest efficiency achieved before surface saturation [24].

4. CONCLUSION

Based on the experimental findings, it can be inferred that guava (Psidium guajava) leaf extract effectively reduces the corrosion rate of low-carbon steel in seawater media. The most favorable performance was achieved at a concentration of 10%, yielding an inhibition efficiency of 73.17%. However, increasing the concentration to 11% resulted in a decline in efficiency to 56.10%. This trend suggests that the inhibition process is governed by the adsorption and formation of a protective film on the steel surface, where performance is strongly influenced by achieving an optimum concentration. Consequently, guava leaf extract demonstrates strong potential for further development as a sustainable and eco-friendly corrosion inhibitor for low carbon steel.

ACKNOWLEDGMENTS

The author would like to express his gratitude to the Politeknik Industri Logam Morowali for the laboratory facilities and guidance provided during this research process.

REFERENCES

[1] S. Wu, W. Xiao, L. Gong, and F. Zhang, “Comparison of Microstructure and Mechanical Properties of Ultra-Narrow Gap Metal Active Gas Arc Welded and Narrow Gap Submerged Arc Welded Q235A Low Carbon Steel,” *Materials*, vol. 16, no. 19, Oct. 2023, doi: 10.3390/ma16196601.

[2] Y. Xu, Q. Zhou, L. Liu, Q. Zhang, S. Song, and Y. Huang, “Exploring the corrosion performances of carbon steel in flowing natural sea water and synthetic sea waters,” *Corrosion Engineering Science and Technology*, vol. 55, no. 7, pp. 579–588, Oct. 2020, doi: 10.1080/1478422X.2020.1765476.

[3] A. I. Yanson, P. Rodriguez, N. Garcia-Araez, R. V. Mom, F. D. Tichelaar, and M. T. M. Koper, "Cathodic corrosion: A quick, clean, and versatile method for the synthesis of metallic nanoparticles," *Angewandte Chemie - International Edition*, vol. 50, no. 28, pp. 6346–6350, Jul. 2011, doi: 10.1002/anie.201100471.

[4] T. J. P. Hersbach and M. T. M. Koper, "Cathodic corrosion: 21st century insights into a 19th century phenomenon," Apr. 01, 2021, *Elsevier B.V.* doi: 10.1016/j.coelec.2020.100653.

[5] J. Chen, Y. Liu, T. Zhang, and M. Wei, "Analytic studies of marine atmospheric corrosion based on multiphysics simulation," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics Publishing, Jun. 2020. doi: 10.1088/1755-1315/508/1/012143.

[6] Z. Hao *et al.*, "Progress of material degradation: metals and polymers in deep-sea environments," Jun. 01, 2025, *Walter de Gruyter GmbH*. doi: 10.1515/corrrev-2024-0009.

[7] H. S. Aljibori, A. Alamiery, and A. A. H. Kadhum, "Advances in corrosion protection coatings: A comprehensive review," 2023, *Russian Association of Corrosion Engineers*. doi: 10.17675/2305-6894-2023-12-4-6.

[8] D. Hermanto *et al.*, "Utilization Of Guava Leaves Extract (Psidium Guajava) As Ecofriendly Corrosion Inhibitor For Iron," *AL-KIMIA*, vol. 7, no. 1, pp. 91–99, 2019.

[9] M. Abdulwahab, L. M. Sani, S. A. Yaro, and O. B. Umaru, "Inhibitive Effect by Psidium Guajava Leaf Extract on The Corrosion of Al-Si-Mg (Ssm-Hpdc) Alloy In Simulated Seawater Environment," Scientific paper, 2015.

[10] L. Suprianti, N. K. Erliyanti, and C. Pujiastuti, "Corrosion Inhibition Effect of the Essential Oil of Dried and Fresh Crystal Seedless Guava Leaves (Psidium guajava) in Acid Medium," *International Journal of Eco-Innovation in Science and Engineering*, vol. 3, no. 01, pp. 12–18, May 2022, doi: 10.33005/ijeise.v3i01.47.

[11] M. Abdulwahab, L. M. Sani, S. A. Yaro, and O. B. Umaru, "Association of Metallurgical Engineers of Serbia AMES Scientific paper UDC: 669," 2015.

[12] Y. M. Pusparizkita, V. A. Fardilah, C. Aslan, J. Jamari, and A. P. Bayuseno, "Understanding of low-carbon steel marine corrosion through simulation in artificial seawater," *AIMS Mater Sci*, vol. 10, no. 3, pp. 499–516, 2023, doi: 10.3934/MATERSCI.2023028.

[13] D. Mardina, E. Ginting, A. Riyanto, and I. A. Abstrak, "Efektivitas Ekstrak Daun Jambu Biji (Psidium Guajava l.) Sebagai Inhibitor Pada Baja Karbon ST37 dalam Medium Korosif NaCl 3%." [Online]. Available: https://jemit.fmipa.unila.ac.id/

[14] "Guide for Laboratory Immersion Corrosion Testing of Metals," May 01, 2004, *ASTM International, West Conshohocken, PA*. doi: 10.1520/G0031-72R04.

[15] D. A. Jones, "Principles and Prevention of CORROSION Second Edition," 1996.

[16] "17. Mars Fontana-Corrosion Engineering(www.iranidata.com)".

[17] F. Gapsari and A. Ganda, "Psidium guajava leaves as corrosion inhibitor of al-6061," in *Materials Science Forum*, Trans Tech Publications Ltd, 2021, pp. 231–236. doi: 10.4028/www.scientific.net/MSF.1045.231.

[18] B. R. Fazal, T. Becker, B. Kinsella, and K. Lepkova, "A review of plant extracts as green corrosion inhibitors for CO2 corrosion of carbon steel," Dec. 01, 2022, *Nature Publishing Group*. doi: 10.1038/s41529-021-00201-5.

[19] S. Noyel Victoria, R. Prasad, and R. Manivannan, "Psidium Guajava Leaf Extract as Green Corrosion Inhibitor for Mild steel in Phosphoric Acid," 2015. [Online]. Available: www.electrochemsci.org

[20] U. L. Ezeamaku, C. B. Ezekannagha, O. I. Eze, I. C. Onyechere, and O. D. Onukwuli, "Corrosion Inhibition of Aluminum using Guava Leaf Extract as an Inhibitor," *Moroccan Journal of Chemistry*, vol. 11, no. 3, pp. 763–779, 2023, doi: 10.48317/IMIST.PRSM/morjchem-v11i3.40322.

[21] P. Vidia Citra, E. Ginting Suka, and A. Riyanto, "Analisis Laju Korosi Baja St37 dengan Inhibitor Ekstrak Daun Jambu Biji dalam Medium Korosif HCl 3% pada Suhu 80°C dan 100°C." [Online]. Available: https://jemit.fmipa.unila.ac.id/

[22] A. Hamza Khalil, M. Ullah, and C. Author, "Sustainable Solution to reduce corrosion rate in mild steel using aqueous and organic extracts of Plants International Journal of Biosciences | IJB |," *J. Biosci*, vol. 12, no. 2, pp. 126–135, 2018, doi: 10.12692/ijb/12.2.126-135.

[23] S. KM, B. M. Praveen, and B. K. Devendra, "A review on corrosion inhibitors: Types, mechanisms, electrochemical analysis, corrosion rate and efficiency of corrosion inhibitors on mild steel in an acidic environment," Aug. 01, 2024, *Elsevier B.V.* doi: 10.1016/j.rsurfi.2024.100258.

[24] A. O. Alao, A. P. Popoola, M. O. Dada, and O. Sanni, "Utilization of green inhibitors as a sustainable corrosion control method for steel in petrochemical industries: A review," Jan. 09, 2023, *Frontiers Media S.A.* doi: 10.3389/fenrg.2022.1063315.

[25] A. Rizi *et al.*, "Sustainable and Green Corrosion Inhibition of Mild Steel: Insights from Electrochemical and Computational Approaches," *ACS Omega*, vol. 8, no. 49, pp. 47224–47238, Dec. 2023, doi: 10.1021/acsomega.3c06548.